An Empirical Analysis of Broadband Access in Residential Multi-Tenant Environments

Steven Kauffman and
Octavian Carare

Federal Communications Commission
Office of Economics & Analytics
OEA Staff Working Paper 49
July 2019

An Empirical Analysis of Broadband Access in Residential Multi-Tenant Environments

Steven Kauffman and
Octavian Carare

OEA Working Paper 49
Office of Economics and Analytics
Federal Communications Commission
Washington, DC 20554
July 2019

Abstract

We use individual-level Census data to analyze the differences in fixed terrestrial broadband subscription rates across occupants of Multi-Tenant Environments (MTEs) and non-MTEs. We find that residential occupants of MTEs are on average slightly less likely to obtain a wireline broadband subscription than residential occupants of non-MTEs. We also evaluate the effect of state mandatory access laws on broadband subscription rates. We find that the presence of a mandatory access law is on average associated with a higher rate of terrestrial fixed broadband subscription for residential occupants of MTEs and non-MTEs. Our estimates suggest that the presence of a mandatory access law increases residential fixed terrestrial broadband subscription rates by 1.8 percentage points in MTEs *after* removing any potential correlation between a household's residential and broadband access choices. This finding indicates that mandatory access laws are associated, on average, with a modest increase in the supply of broadband in MTEs. We hypothesize that this increase in subscription rates may be a result of a reduction in the marginal, or fixed, cost of supplying broadband or the result of increased consumer choices.

An Empirical Analysis of Broadband Access in Residential Multi-Tenant Environments

Steven Kauffman and Octavian Carare[1]

1. Introduction

Various jurisdictions across the United States have passed laws with the intent of expanding broadband deployment inside Multi-Tenant Environments (MTEs). Mandatory access laws prohibit MTE building owners from interfering with the ability of service providers to install facilities for use in offering service to a tenant.

As indicated in Table 1 below, mandatory access laws differ with respect to the type of service providers they apply to, such as franchised cable operators or multichannel video programming distributors. These laws often explicitly require that the service provider pay the costs associated with installing wiring. (*See, e.g.*, Wis. Stat. Ann. § 66.0421(4)). None of the state mandatory access laws listed in Table 1 require that building owners make wiring owned by the building owner available for sharing by service providers.

While most statutes prohibit an MTE owner from interfering with the installation of broadband equipment, several go further and explicitly prohibit some types of agreements. In this paper, we focus on the effects on broadband adoption of the existence of *any* type of state mandatory access law.[2]

Economic theory does not have a clear-cut prediction about how mandatory access laws affect broadband subscribership. On the one hand, mandatory access laws could increase broadband adoption by prohibiting access limitation agreements between an Internet Service Provider (ISP) and MTE owners that tend to limit consumer choice. On the other hand, mandatory access laws could decrease broadband adoption if prohibiting access limitation agreements between an ISP and the MTE landlord increase the cost of deployment or decrease the rate of return from investments in broadband infrastructure. In this paper, we provide some empirical evidence of how these laws affect broadband uptake in MTEs.

Approximately one-third of Americans live in apartment buildings and condominiums, which are considered residential MTEs. Despite this, there is a dearth of empirical evidence concerning the differences in broadband subscription rates between MTE and non-MTE residents. We were not able to find in the economics literature any investigation of the effect of the presence of a state mandatory access law on broadband subscription rates among MTE and non-MTE residents. In this paper, we address this apparent lack of empirical evidence by

[1] Office of Economics and Analytics, Federal Communications Commission.

[2] Fixed terrestrial broadband connections include broadband connections provided over any terrestrial technology, such as cable, DSL, or optical, and exclude fixed broadband connections provided over other means, such as satellite or wireless, or mobile connections. For reading fluidity, we will refer to "fixed terrestrial broadband" as either "fixed terrestrial broadband" or the defined variable "broadband."

analyzing Census data about Americans' residential choices between MTEs and non-MTEs, and their broadband access choices.

The higher household density of MTEs may be associated with lower costs of provisioning broadband service, which may contribute to an increased supply of broadband in MTEs relative to non-MTEs. However, installing broadband facilities in MTEs presents several challenges that may increase the cost of deployment. For example, laying plant or repairing equipment may be costlier in MTEs than in non-MTEs. Or, the fact that at least three parties must typically coordinate in order for broadband deployment to occur—the broadband provider, the building owner, and the tenant (rather than just the provider and owner in single-family homes)—may make deployment more difficult. These challenges may reduce the supply of broadband in residential MTEs relative to residential non-MTEs.

The paper proceeds as follows: Section 2 describes our dataset and presents summary statistics. Section 3 describes our empirical strategy. We present a summary of our results in Section 4. Section 5 provides a short discussion and conclusions.

2. Data

We obtained individual-level information on demographic characteristics, broadband subscription, and household residential choices from the Public Use Microdata Sample (PUMS) of the 2017 American Community Survey (ACS) 1-year estimates.[3] This dataset contains responses to the ACS questions for a sample representing approximately one percent of the United States population. The ACS provides information on age, race, and education level for the head of household, as well as the number of occupants and total income of the household.

As of December 2016, a total of 16 states and the District of Columbia had adopted some form of mandatory access law. Information on the timing and details of these policies comes from the Wireline Competition Bureau of the Federal Communications Commission; it is listed in Table 1 and a map is shown in Figure 1. Using this information, we created a yes/no indicator for the presence of a mandatory access law for every state in the country, with two exceptions: Florida and Iowa. Florida adopted a mandatory access law that applies to condominium buildings, but not to apartment buildings. Because we are not able to differentiate between apartments and condominiums in the data available to us, we removed Florida from our sample. The Iowa statute is somewhat ambiguous; as a result, we also excluded Iowa from our analysis.[4]

ACS responses indicate if a household has a terrestrial fixed broadband subscription. If a respondent answered "Yes" to the question "Do you or any member of the household have access to the Internet using a broadband (high speed) Internet service such as cable, fiber optic,

[3] ACS is an ongoing survey of the Census Bureau. It is the largest household survey administered by the Census Bureau; it collects annually information from approximately 3.5 million households concerning e.g. income, ancestry, education, and, importantly for our analysis, residential choice and broadband access information. For more information, consult https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_pums_csv_2017&prodType=document.

[4] Although the Iowa law is cited in law journals, its content is unclear. We repeated our analysis by also including the Florida and Iowa data, for which we identified a mandatory access law. We found no significant differences in the results relative to the results that we present here.

or DSL service installed in this household?", then we mark that household as having a broadband subscription.[5] The ACS asks separate questions for cellular, satellite, and dial-up Internet plans. The question of interest to us only refers to fixed terrestrial broadband.

Table 1: Mandatory Access Laws (MAL)

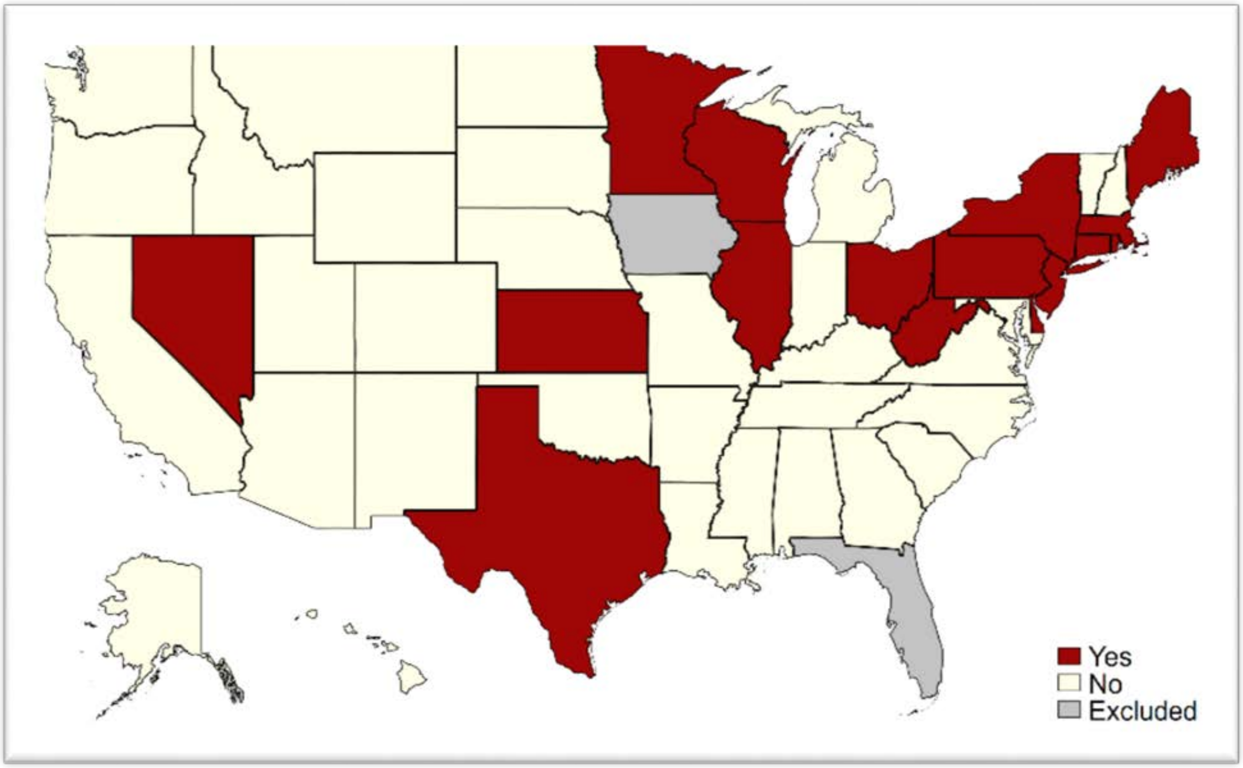
State / Territory	MAL: Cable Operators	MAL: MVPDs	MAL: Telecom Providers	Date Adopted
Connecticut	✓			1975
Delaware	✓			1974
District of Columbia	✓			1982
Illinois	✓			1990
Kansas			✓	1975
Maine	✓			1987
Massachusetts	✓			1975
Minnesota	✓			1985
Nevada		✓		1987
New Jersey	✓			1972
New York	✓			1995
Ohio			✓	2010
Pennsylvania	✓			1951
Rhode Island			✓	1986
Texas			✓	1997
West Virginia	✓			1999
Wisconsin		✓		1989

Source: Wireline Competition Bureau, Federal Communication Commission.

The ACS survey also asks respondents to identify the type of structure where the household is located. Each respondent answered the question "Which best describes this building?" by selecting one of ten options. We classify a household as residing in an MTE if respondents indicate that the building contains two or more units. Since our hypotheses center on the difference between MTE and non-MTE households, respondents that report living in either "A Mobile Home" or "Boat, RV, van, etc." were removed from our sample.

[5] In the present context, the term access is used to mean the ability of a household's members to access the Internet in their residence using a fixed terrestrial connection. Since another meaning of access may relate to the deployment of a terrestrial wireline connection to the residence, to avoid any misunderstanding we refer to a household that answers this question in the affirmative as having a broadband subscription.

Figure 1: States with Mandatory Access Laws



Source: Wireline Competition Bureau, Federal Communication Commission.

We present summary statistics for the household demographic characteristics in Table 2 below. Summary statistics are presented for the entire sample, as well as for MTE/non-MTE households, and for states with and without mandatory access laws. Table 2 indicates that there are some clear differences between the demographic characteristics of households in states with and without a mandatory access law.

For example, households in states with mandatory access laws have, on average, higher incomes, as well as a slightly higher rate of college completion. In fact, we tested statistically the means of all the demographic characteristics for residents of states with and without a mandatory access law. We found that while these averages are quite close, as indicated in Table 8 in the Appendix, the differences between the average values of each demographic characteristic (except high school completion rates and the proportion of individuals older than 60) are statistically significant.

It is interesting to note that MTE households represent a higher proportion of total households in mandatory access states than in states without a mandatory access law (23.1% in states with a mandatory access law, versus 17.7% in states without a mandatory access law). This, in addition to other differences in Table 2 above, suggest there may be some inherent differences between MTE residents in states that have mandatory access laws and those that do not.

Table 2: Summary Statistics, Demographic Characteristics

	All States		States without MAL		States with MAL	
	Mean	St Dev	Mean	St Dev	Mean	St Dev
All Households						
Broadband Subscription	0.83	0.38	0.82	0.38	0.84	0.37
Household Income [000s]	94.94	96.92	93.09	92.93	97.32	101.80
Number of Residents	2.61	1.46	2.63	1.48	2.59	1.44
Age	50.29	16.21	50.21	16.29	50.40	16.12
No Children Present	0.66	0.47	0.66	0.47	0.67	0.47
Over 60	0.35	0.48	0.35	0.48	0.35	0.48
Married	0.55	0.50	0.55	0.50	0.54	0.50
Completed High School	0.93	0.25	0.93	0.25	0.93	0.25
Completed College	0.16	0.37	0.16	0.37	0.17	0.37
Asian	0.06	0.23	0.06	0.24	0.05	0.22
Black or African-American	0.11	0.32	0.12	0.32	0.11	0.31
Hispanic	0.12	0.33	0.11	0.32	0.13	0.34
White	0.76	0.42	0.75	0.43	0.78	0.41
Number of observations	924,540		521,956		402,584	
Non-MTE Households						
Broadband Subscription	0.84	0.37	0.83	0.38	0.85	0.36
Household Income [000s]	104.61	100.42	102.03	97.29	108.27	104.61
Number of Residents	2.78	1.48	2.78	1.50	2.77	1.44
Age	52.48	15.36	52.32	15.49	52.71	15.16
No Children Present	0.64	0.48	0.64	0.48	0.64	0.48
Over 60	0.40	0.49	0.39	0.49	0.40	0.49
Married	0.64	0.48	0.63	0.48	0.64	0.48
Completed High School	0.94	0.24	0.94	0.24	0.94	0.23
Completed College	0.17	0.38	0.17	0.37	0.17	0.38
Asian	0.05	0.21	0.05	0.22	0.04	0.20
Black or African-American	0.09	0.29	0.10	0.30	0.08	0.26
Hispanic	0.10	0.30	0.10	0.30	0.11	0.31
White	0.81	0.39	0.79	0.41	0.84	0.36
Number of observations	738,726		429,317		309,409	
MTE Households						
Broadband Subscription	0.80	0.40	0.80	0.40	0.81	0.39
Household Income [000s]	65.51	78.35	60.65	65.43	70.23	88.86
Number of Residents	2.12	1.31	2.10	1.28	2.15	1.33
Age	43.64	16.92	42.54	16.80	44.70	16.97
No Children Present	0.74	0.44	0.74	0.44	0.74	0.44
Over 60	0.22	0.42	0.20	0.40	0.24	0.43
Married	0.28	0.45	0.27	0.44	0.29	0.46
Completed High School	0.91	0.29	0.91	0.28	0.91	0.29
Completed College	0.15	0.35	0.13	0.34	0.16	0.37
Asian	0.08	0.28	0.09	0.29	0.08	0.27
Black or African-American	0.19	0.39	0.19	0.39	0.19	0.39
Hispanic	0.18	0.38	0.16	0.37	0.19	0.39
White	0.62	0.48	0.62	0.49	0.63	0.48
Number of observations	185,814		92,639		93,175	

Source: U.S. Census Bureau, 2017 American Community Survey 1-Year Estimates and author calculations. MAL is an abbreviation of Mandatory Access Law.

In Table 3 below, we collect the average broadband uptake rates by type of building (MTE or non-MTE), for states with and without a mandatory access law.

Table 3: Average Broadband Uptake Rates

	All States	States w/o Access Law	States w/ Access Law	F-statistic	P-value
Non-MTE Households	0.8377	0.8286	0.8506	407	0.0000
MTE Households	0.8043	0.7957	0.8125	51	0.0000
F-statistic	677	321	446		
P-value	0.0000	0.0000	0.0000		

Note: The F-statistics correspond to tests of the null hypothesis of pairwise equality between the estimates in each row and column of the table; the null is always rejected at confidence levels greater than 99.99%.

3. Empirical Strategy

The presence of a mandatory access law has two *potential* effects on broadband uptake by MTE residents. The direct effect of primary interest to us is a change—brought about by the law—in the cost of supplying broadband to MTE residents. As we discussed in the Introduction, mandatory access laws may in principle either facilitate or hinder the provision of broadband in MTEs by reducing or increasing the cost of supplying broadband. In addition, the possibility of increased access by multiple providers may result in lower prices and higher levels of adoption. Economic theory does not offer a clear prediction of whether mandatory access laws bring about, on average, an increase or decrease in such costs.

A second, indirect effect of mandatory access laws on broadband uptake in MTEs is through the potential effect that access laws have on the households' choices to reside in an MTE. Factors associated with the presence of a mandatory access law (but not necessarily the law itself) may bring about changes in the characteristics of the MTEs, or the preferences of their residents for these characteristics, in such a way that the set of MTE residents in a mandatory access state are more (or less) likely to choose to acquire a broadband subscription than MTE residents in a state with no mandatory access law. This second, indirect effect may act as a confounder for the direct effect of primary interest to us.[6]

Our empirical strategy for distinguishing these effects is as follows. We first analyze the effect of state mandatory access laws on broadband subscription rates to see if mandatory access laws have any effect at all. We then seek to evaluate the differential effect the presence of access laws may have on the rates of broadband subscription for MTE and non-MTE residents. Finally, we seek to evaluate how much of the observed differences in the rates of broadband uptake are

[6] This is akin to the selection bias that needs to be considered when evaluating the effectiveness of a medical treatment when factors that are associated with the selection of patients into the treated and control groups may also be associated with the probability of success of the medical treatment. We discuss this in more detail below.

correlated with the presence of a state mandatory access law. We discuss each component of our empirical strategy in more detail below.

3.1. Effect of mandatory access laws on broadband subscription rates

Our first question concerns the effect of mandatory access laws on the likelihood of broadband subscription. To answer this question, we estimate a logit model with the following specification:

$$Broadband\ Subscription_i = \alpha + \beta_1 MAL + \beta_2 X_i + \beta_3 \delta_D + \varepsilon_i,$$

where *i* indexes households. $The\ vector\ X_i$ contains demographic characteristics of the household.[7] *Broadband Subscription*, the binary dependent variable, is equal to 1 if the respondent reports a broadband connection, and zero otherwise. *MAL* is a binary variable that equals 1 if *any* type of mandatory access law is in effect in the household's state, and zero otherwise.

The coefficient of interest β_1 indicates the observed effect that the presence of a state mandatory access law has on the probability that a household has broadband access. A positive/negative value of β_1 indicates that states with a mandatory access law have—keeping all else constant—higher/lower broadband subscription rates than states without an access law. The variables δ_D represent Census Division-level fixed effects that help to soak up unobserved factors that affect broadband subscriptions and are invariable across all households in a Census geographic division.[8]

3.2. Differential impact of access laws for MTEs and non-MTE households

Our second question concerns the differential effects of the presence of a mandatory access law on broadband subscription for MTE and non-MTE households. To evaluate these effects, we estimate a second logit specification:

$$Broadband\ Subscription_i = \alpha + \beta_1(MAL * MTE_i) + \beta_2(MAL * nonMTE_i) + \beta_3 X_i + \beta_4 \delta_D + \varepsilon_i,$$

where (*MAL*MTE*) and (*MAL*nonMTE*) are two binary variables, equal to 1 for respondents residing in MTEs in mandatory access states and for residing in non-MTEs in mandatory access states, respectively, and zero otherwise. The coefficients β_1 and β_2 help us evaluate the effects of a mandatory access law on the probability of broadband subscription for MTE and non-MTE households.

[7]The actual demographic variables we used are given in Table 4 below.

[8] These variables may control for potential regional effects such as differences in tastes for broadband that correlate with e.g. climate or weather patterns. There are nine Census geographic divisions in the United States.

3.3. Estimated effect of mandatory access laws on broadband uptake

Finally, in the third step of our empirical approach, we want to measure the effect of a mandatory access law on the likelihood of obtaining broadband access *independent* of a household's decision to reside in an MTE.[9]

It is perhaps easier to think of this problem in a potential-outcomes framework. Consider the following four possible "treatments" that each household can be exposed to:

- Household is in a **non-MTE** in a state that **has not adopted** an access law;
- Household is in a **non-MTE** in a state that **has adopted** an access law;
- Household is in an **MTE** in a state that **has not adopted** an access law; or
- Household is in an **MTE** in a state that **has adopted** an access law.

We would like to estimate if the combination of residential type and presence, or lack, of an access law (the "treatment") affects a household's decision to acquire broadband access. Further, if there is an effect, we want to estimate the magnitude of each treatment effect. Ideally, one would want to observe a household's broadband choice for each of the four treatments. If so, one could compare the average outcomes across all households exposed to a treatment and determine its average effect on broadband subscription. This is of course not possible, since the observations in our data show each household being exposed to only one treatment, and thus we observe only one outcome for each household.[10]

To estimate the average effect of each treatment, we use a statistical technique called inverse-probability weighting. This method is based on an estimator developed by Horvitz and Thompson (1952).[11] The method involves a weighting scheme to create a pseudo dataset of households where the treatment received is independent of covariates. The first step consists of estimating a household's probability of receiving each of the four treatments. We model this using a multinomial logistic regression where the outcome is the treatment observed and the determinants consist of household-level demographics. Each household is then assigned a weight equal to the inverse of its probability for each treatment.[12]

[9] This is not unlike evaluating the effectiveness of a new medical treatment. In the absence of clear random assignment into treatment and control groups, evaluating of effectiveness of treatment during a trial ought to allow for non-random selection of individuals into the treated and control groups. If members of the treated group self-select to some extent based on characteristics that may also affect the likelihood of successful treatment, then treatment success rates calculated as simple averages of the outcomes in the treatment group may be biased estimates of the actual treatment effect. In our case, removing the effect of residential choice on broadband access allows us to estimate the effect of MAL on the likelihood of broadband access—under the maintained assumption that selection into treatment and control groups is based on variables observable to us—*as if* individuals are randomly assigned to reside in an MTE or non-MTE. A measure of this effect may be indicative of the direct effect of MAL on the supply of broadband in MTEs; for example, a positive estimate may indicate that the supply of broadband is increased in mandatory access states relative to states with no mandatory access laws, perhaps due to lower deployment costs, or a reduced marginal cost of supplying broadband in MTEs.

[10] While randomized controlled trials have become the gold standard to estimate treatment effects, randomly assigning households to MTEs/non-MTEs in states with or without mandatory access is not a feasible option.

[11] Horvitz, D. G., and D. J. Thompson, (1952). A generalization of sampling without replacement from a finite universe, .*Journal of the American Statistical Association* 47: 663–685.

[12] We use inverse probability weighting because of its feasibility and computational convenience relative to other methods (see, e.g., Lopez, M.J. and Roee Gutman (2017), Estimation of causal effects with multiple treatments: a review and new ideas, mimeo, Brown University).

Mathematically, this can be expressed as:

$$W_{iz} = \frac{Z_i}{P(Z_i=1\,|X_i)} + \frac{1-Z_i}{P(Z_i=0\,|X_i)},$$

where W represents the weight assigned for household *i* and treatment *z*, Z represents treatment assignment ($Z_i = 1$ for a treated household, $Z_i = 0$ for an untreated household), P represents the probability of a given outcome, and X is a vector of household demographics. This produces large weights for two types of households: those that receive the treatment but have a low estimated probability of treatment, and those that are untreated, but have a high estimated probability of treatment.

We calculate next the weighted average of the outcome variable (broadband access) for each treatment. The estimator can be written analytically as:

$$E(\overline{Y_{iz}}) = \left(\frac{1}{N} \right) * \sum_{i=1}^{N} (Y_i * W_{iz})$$

where $E(\overline{Y_i})$ represents the expected broadband subscription outcome for household i, N is the number of households, and W_{iz} is the weight calculated using the above formula.

4. Results

Table 4 presents the results of our logit models that are aimed at uncovering the factors associated with higher or lower rates of broadband uptake. The results suggest that mandatory access laws have a positive and statistically significant effect on the likelihood of having a broadband subscription. This effect is not necessarily a causal one; it only reflects a positive association existent in the data—when all other factors are kept constant—between the presence of a mandatory access law and higher rates of broadband uptake. We find that, while the access laws are aimed at MTEs, the presence of an access law is associated, on average and all other things equal, with higher rates of broadband subscription in non-MTE buildings as well.[13]

One might speculate that, in part, this could reflect externalities—either in the supply of broadband services, or in the consumption thereof—associated with increased adoption by MTE consumers. This may also reflect variables unobserved in our data that, in part, affect the households' likelihood of receiving a particular treatment. Teasing out these effects may be an interesting subject of future research.

The estimates in Table 4 also indicate that the likelihood of acquiring broadband access is higher — keeping all other things equal — for households that have higher income, more household members, as well as for households whose members are younger and married, have completed either high school or college, or are White, or Asian.

[13] This positive association between rates of broadband adoption and the presence of a mandatory access law may not reflect a causal relationship between these two variables.

Table 4: Broadband Subscription Choice

	Model 1	Model 2
MAL	0.1641^{***}	
MAL * MTE		0.1222^{***}
MAL * non-MTE		0.1791^{***}
log(Household Income)	0.3102^{***}	0.3088^{***}
Number of Household Members	0.0125^{**}	0.0115^{**}
Age	-0.0115^{***}	-0.0120^{***}
Age*Age	0.1219^{***}	0.1277^{***}
No Children Present	-0.0407^{***}	-0.0396^{**}
Married	0.1526^{***}	0.1496^{***}
Completed High School	0.5450^{***}	0.5436^{***}
Completed College	1.1323^{***}	1.1344^{***}
Asian	0.3736^{***}	0.3758^{***}
Black	-0.1610^{***}	-0.1591^{***}
Hispanic	-0.2746^{***}	-0.2708^{***}
White	0.1493^{***}	0.1464^{***}
Completed College * Age	-0.0123^{***}	-0.0124^{***}
Constant	-1.6637^{***}	-1.6090^{***}
Census Division Fixed Effects	Yes	Yes
Number of Observations	916,374	916,374
Pseudo R^2	0.0505	0.0506

Notes: The dependent variable is equal to 1 if a household subscribes to broadband, and zero otherwise. Robust standard errors: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Because the impact of changes in each explanatory variable on the likelihood of broadband access is a nonlinear function of the estimated coefficients, in Table 5 we present a few marginal effects of interest. Marginal effects are the estimated probabilities of observing broadband access for different combinations of the MAL and MTE variables. For example, the logit estimates imply that, at the mean of the other variables, 81.3% of MTE households in states that do not have a mandatory access law subscribe to broadband. This is 2.4 percentage points lower than the corresponding estimate of 83.7% for MTE households in mandatory access states, a difference that is statistically significant, as indicated by the p-value of less than 0.01%.

Overall, while broadband access rates in non-MTEs are higher than in MTEs, the differences are relatively small, but statistically significant.[14] By direct comparison with the corresponding numbers in Table 3, it appears that a significant portion of the differences in broadband access rates corresponding to different mandatory access laws and household decisions to live in an MTE or not can be attributed to different demographic characteristics of

[14] Table 3 differs from Table 5 because Table 3 presents simple averages calculated from the data. Since households in states with and without mandatory access laws have, on average, different characteristics, it is likely that differences in demographic characteristics drive some of the observed differences in broadband access rates. To construct Table 5, we set the characteristics of households (other than the MTE and MAL indicators) to the average for all households, and used the logit estimates to calculate predicted broadband access rates for different MTE and MAL situations. In doing so, we have removed the role of variables other than MTE and MAL on broadband access; that is why the numbers in Table 5 are different from the corresponding numbers in Table 3.

residents in states with and without mandatory access laws. We explore the role of these differences in explaining residential choice between MTEs and non-MTEs next.

Table 5: Marginal Effects

	No Mandatory Access Law	Mandatory Access Law	Chi^2	P-value
Non-MTE Households	0.8427	0.8633	225	0.0000
MTE Households	0.8135	0.8372	221	0.0000
Chi^2	1,902	2,063		
P-value	0.0000	0.0000		

Notes: Marginal effects are calculated at the mean of the data using the logit estimates corresponding to Model 1 in Table 4. The χ^2 statistics correspond to tests of the null hypothesis of pairwise equality between the estimates in each row and column of the table; the null is always rejected at confidence levels greater than 99.99%.

In Table 6 below, we report estimates of the factors associated with a household's decision to reside in an MTE, estimated using a logit model. The results indicate that—holding all else equal at the mean of the data—a household is nearly 23% more likely to live in an MTE in a state that has enacted a mandatory access law than in a state that did not enact such a law.[15]

Table 6: Determinants of Residing in an MTE

	Reside in MTE
MAL	0.4619***
log(Household Income)	-0.3562***
Number of Residents	-0.3307***
Age	-0.1238***
Age ^ 2	1.4198***
No Children Present	0.1786***
Married	-0.7750***
Completed High School	-0.3777***
Completed College	0.3665***
Asian	0.5741***
Black or African-American	0.4986***
Hispanic	0.6658***
White	-0.4667***
Completed College * Age	-0.0038***
Constant	10.8707***
Census-Division Fixed Effects	Yes
Number of observations	916,374
Pseudo R^2	0.2259

Notes: The dependent variable is equal to 1 if a household resides in an MTE, and zero otherwise. Significance levels are established using robust standard errors: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

[15] We do not imply that the presence of a state mandatory access law has a causal effect on the residential choices of households in that state. This difference may be attributed to variables unobserved in our data.

Because these laws appear to be significantly associated with the households' residential choices, the laws may indirectly be associated with broadband access rates because the characteristics of households residing in MTEs in states with or without an access law are different. As such, observing a higher rate of broadband access in MTEs may offer little indication about the potential effects of the law on the supply of broadband in MTEs. We tackle this issue next.

Our final question is aimed at unearthing the effect of mandatory access laws on the relative ease of supplying broadband access or the possibility of greater consumer choice in MTEs. Conceptually, what we aim to mimic with our estimation procedure is a situation where households are randomly assigned to reside in an MTE or not, and to a state that either has an access law, or doesn't. If we subsequently observe, say, a higher rate of broadband access for MTE residents in states with an access law relative to MTE residents in states without such a law, then, given random residential assignment, the higher access rate is attributable to factors that increase the supply of broadband in MTEs in mandatory access states, and not to potential broadband demand differences that have been washed away through random assignment.

It is important to note here that our estimated treatment effects are obtained under the standard assumption of unconfoundedness (or conditional independence) whereby adjusting for differences in covariates between the households in the treated and control groups removes any potential bias caused by selection into the treatment group.[16] Unconfoundedness fails if the unobserved factors that affect selection of households into treatment and control groups are correlated with the residential and broadband choices of households. If, for example, one such unobserved variable increases—conditional on the values of all observed variables—the likelihood of a household residing in an MTE in access law states (but not in states with no mandatory access law) and the likelihood of obtaining a broadband subscription, then the measured effect of the presence of a state mandatory access law on broadband subscription in MTEs is likely overstated.

The results of the inverse-probability weighting model are in Table 7. The estimates indicate that adopting a mandatory access law is associated on average with an increase in broadband subscription rates for MTE households by approximately 1.8 percentage points. Of note, mandatory access laws are also associated with a smaller average increase of approximately 1.5 percentage points in broadband subscription rates for non-MTE households. These increases are estimated by removing the selection effect by which the presence of a mandatory access law may change the characteristics, and the demand for broadband, of households living in MTEs and non-MTEs.

The estimated average treatment effects indicate that the increase in broadband subscription rates in MTEs in mandatory access states may be due to factors associated with the presence of a mandatory access law that help lower the marginal cost of supplying broadband in MTEs, or lower the fixed cost of supplying broadband in MTEs, or both. This result may also reflect increased broadband choices available to consumers in mandatory access states.

---

[16] See Rubin, D. (1990), Formal Mode of Statistical Inference for Causal Effects, *Journal of Statistical Planning and Inference* 25, pp. 279-292. For a defense of the assumptions that underlie the estimation of treatment effects, see Imbens, G.W. (2004), Nonparametric Estimation of Average Treatment Effects under Exogeneity: A Review, *Review of Economics and Statistics* 86(1), pp. 4-29.

Table 7: Treatment Effects

	States without MAL	States with MAL
Means of Potential Outcomes		
Non-MTE Households	0.8194***	0.8346***
MTE Households	0.8272***	0.8454***
Average Treatment Effects		
Non-MTE Households	Base Outcome	0.0152***
MTE Households	0.0078**	0.0259***

Notes: The table contains estimates of the inverse probability weighting model. The first part of the table contains the means of the potential outcomes (broadband access rates) for different mandatory access law (MAL) and MTE scenarios. The second part of the table contains the treatment effects relative to the non-MTE, non-MAL base outcome. Significance levels indicated by asterisks: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

While we cannot claim that we control for all the factors driving the selection of households into the treatment and control groups, we can show several diagnostic results that are consistent with random assignment conditional on the observed household characteristics. If our statistical procedure achieves balanced results similar to random assignment, then the weighted distribution of each covariate for the control and treatment groups should be similar. Figures 3 and 4 in the Appendix show results consistent with random assignment.

5. Conclusion

We analyzed cross-sectional household-level Census data on the residential and broadband access choices of American households in 2017. Our analysis indicates that the presence of a mandatory access law is associated, on average, with an increase of about 2.4 percentage points in the fraction of households living in MTEs that have a broadband subscription. The presence of a mandatory access law is also associated, on average, with an increase of about 2 percentage points in the fraction of households living in non-MTEs that have a broadband subscription.

In part, this increase can be attributed to observed factors such as income and age that are likely determinants of both residential choice and broadband demand. However, our average treatment effect estimates indicate that a significant portion of this increase (approx. 1.8 percentage points for MTEs, and approx. 1.5 percentage points for non-MTEs) may be associated with factors related to the presence of mandatory access laws that increase the supply of broadband. As stated above, we hypothesize that the increase in broadband uptake in MTEs in mandatory access states may be the result of a reduction in either the marginal or the fixed cost of supplying broadband in MTEs or the result of an increase in consumer choice.

Finally, it is important to note that our method of analysis—and indeed any method of analysis that, like our study, relies on observational data—cannot rule away the existence of factors *not observed* in our data that (1) differ systematically across households in states with and without mandatory access; and, (2) affect both the housing and broadband subscription choices of the households in our sample.

Further steps in the direction of this research could involve exploring the existence and effects of such variables on broadband uptake. Methods of analysis other than those explored here may also yield valuable insight. For example, a potentially fruitful avenue of research is to employ a geographic discontinuity approach[17] that exploits changes in the mandatory access law across the boundaries of PUMAs. In addition, it would be useful to explore the extent to which production or consumption externalities associated with the presence of mandatory access laws bring about an increase in broadband subscription in MTEs and *non*-MTEs.[18]

[17] See e.g., Keele, L.J. and Rocio Titiunik (2015), Geographic Boundaries as Regression Discontinuities, *Political Analysis* 23, pp. 127-155 and the references therein.
[18] This may require using an augmented dataset that includes detailed broadband supply data, or data that have a longitudinal component.

Appendix

An important step in implementing inverse-probability weighting is to ensure covariate balance among households across treatment groups. When there is balance among observed covariates, it can be assumed that there is also balance among unobserved covariates. This assumption is essential because it allows for differences among outcomes to be attributed to the effect of the treatment. Below are two density plots showing the distribution of household income and the age of the head of household across the four types of treatment. These are produced using unweighted and weighted samples and show that our samples are fairly balanced for these characteristics.[19]

Figure 2: Distribution of Incomes

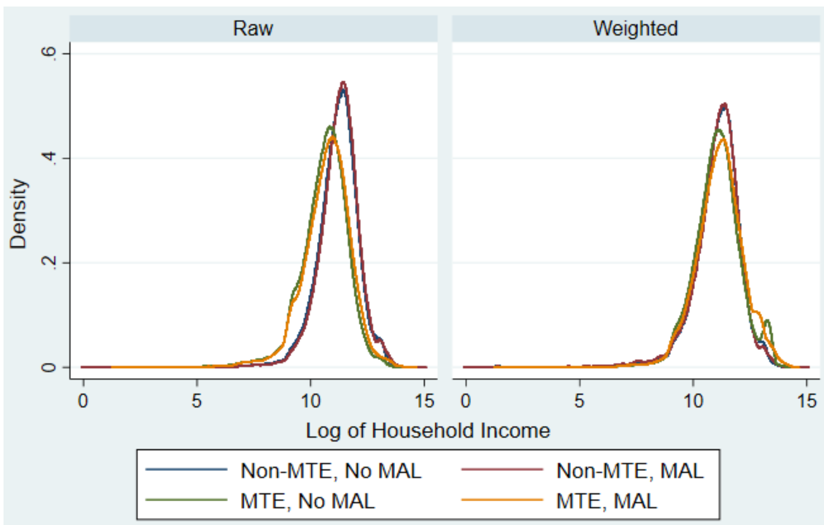
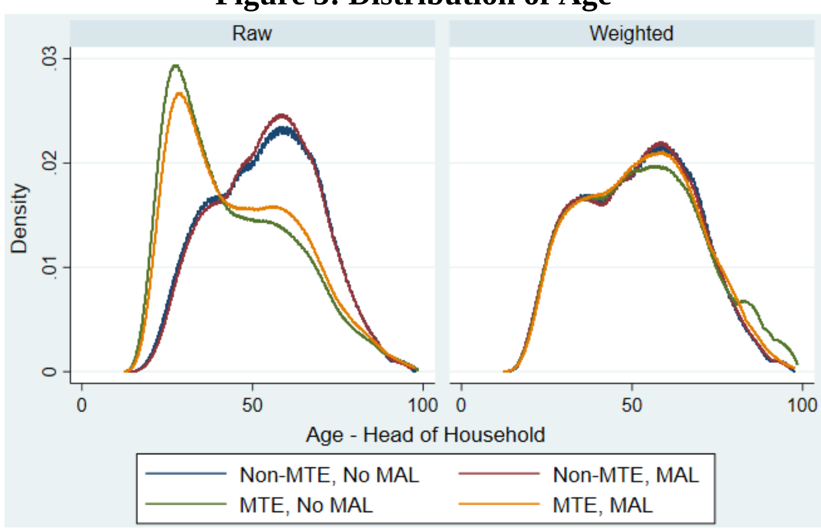


Figure 3: Distribution of Age



[19] Similar plots were created for all covariates but were not included. The distributions of covariates across treatments for the weighted samples look very similar to those that were included.

Table 8: Comparison of Means

	Non-MAL States	MAL States	Difference	Standard Error	P-value
Broadband Subscrip. Rate	0.82	0.84	0.02	0.00	0.00
Log (Household Income)	11.07	11.09	0.03	0.00	0.00
Number of Occupants	2.63	2.59	-0.04	0.00	0.00
Age	50.21	50.40	0.20	0.04	0.00
No Children Present	0.66	0.67	0.01	0.00	0.00
Over 60	0.35	0.35	0.00	0.00	0.44
Married	0.55	0.54	-0.01	0.00	0.00
Completed High School	0.93	0.93	0.00	0.00	0.88
Completed College	0.16	0.17	0.01	0.00	0.00
Asian	0.06	0.05	-0.01	0.00	0.00
Black or African-American	0.12	0.11	-0.01	0.00	0.00
Hispanic	0.11	0.13	0.02	0.00	0.00
White	0.75	0.78	0.03	0.00	0.00

FEDERAL COMMUNICATIONS COMMISSION
U ★ S